Observations And Simulations Of Diurnal Effects Contributing To The Modification Of The Coastal Marine Atmospheric Layer

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LONG-TERM GOALS

The goal of this project is to increase our understanding of the modification of complex atmospheric dynamics, cloudiness, and fog due to the interaction of the air, sea, and land in a coastal region. This increased understanding will lead to improvements in parameterizations of turbulence, cloudiness, and fog. In general, it will improve the episodic and seasonal forecasting of coastal weather over a wide spectrum of spatial and temporal scales.

OBJECTIVES

Specific project objectives include: 1) investigating the physical processes that lead to the formation, evolution, and dissipation of offshore fog; and 2) investigating the diurnal variability of the dynamics and cloudiness of the marine atmospheric boundary layer off the California and Oregon coasts. The project is supported by the Office of Naval Research, Marine Meteorology and Atmospheric Effects.

APPROACH

In order to understand the evolution of the marine atmospheric boundary layer that leads to the formation of offshore fog, we designed a numerical experiment that simulates atmospheric processes in the cloudy marine layer along over-water trajectories in the presence of large-scale subsidence and a strong low-level inversion (Koracin et al. 2000b). We used a one-dimensional, second-moment, turbulence-closure boundary layer model (Koracin 1989, Koracin and Rogers 1990, Rogers and Koracin 1992, Leipper and Koracin 1998, Koracin et al. 2000b) in a Lagrangian framework to study the fog formation process. Results from the simulation are then compared to meteorological data (buoys, radiosondes, satellite) at various points along the trajectory.

In the previous study of coastal dynamics, we developed the concept of short-term mesoscale “climatology” of the West Coast weather in June and July 1996 using Mesoscale Model 5 (MM5) (Koracin et al. 1997, 1998; Koracin and Dorman 2000). These extensive simulations with 9 km

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horizontal resolution covering the northern and central California coast were run with limited computer resources using Version 1 of the MM5 model and simple moisture parameterization. In order to extend the investigation of the predictability of cloudiness and the characteristics of its diurnal variation, we have used Version 3 of the MM5 model with the same grid setup, but with mixed phase cloud parameterization to simulate all of the types of cloudiness necessary for comparison with satellite data.

WORK COMPLETED

We performed a series of one-dimensional simulations ranging from two- to five-day duration. The high-resolution vertical grid had 180 points ranging from the sea surface to 1200 m AGL. By varying SST in time (2° C over 48 hours), the model emulates the advection of the marine-layer slab over increasing SST along the trajectory from the northern to central California waters. Many sensitivity tests were conducted. The main tests included weak (5 K), reference (10 K), and strong (15-25 K) inversion strength; subsidence velocities corresponding to weak ($2 \cdot 10^{-5}\ s^{-1}$), reference ($3 \cdot 10^{-5}\ s^{-1}$), and strong ($4 \cdot 10^{-5}\ s^{-1}$) synoptic divergence; various initial marine layer depths and associated cloud top locations (200 to 700 m); as well as "dry" (mixing ratio of water vapor of 1 g kg^{-1}) and "wet" (mixing ratio of water vapor of 5 g kg^{-1}) conditions of the air above the inversion. Details on the model parameterizations and setup can be found in Koracin et al. 2000b.

We completed a month-long simulation of the West Coast mesoscale weather using Version 3 of the MM5 model. In contrast to the previous numerical experiment using Version 1 of the MM5 model with the Blackadar PBL and simple moisture schemes (Koracin et al. 1997, 1998; Koracin and Dorman 2000), the focus of this new numerical experiment was on detailed explicit moisture (treatment of mixed-phase clouds) and turbulence (Eta PBL) schemes. We kept the model setup the same as in the previous experiment. For the case study from 25 to 28 June 1996, which was characterized by variability in the wind speed and direction along almost all of the coast, we also completed additional simulations using the same model setup, but with the Burk-Thompson (prognostic TKE) scheme.

For the three case studies in June 1996 (7-8, 17-18, and 23-24), we performed high-resolution MM5 simulations covering the northern and central California coast with a horizontal resolution of 2 km. The main purpose of these additional simulations was to reveal the characteristics of transient occurrence of long gravity waves along the California coast. For these simulations we chose the Burk-Thompson TKE scheme and the explicit moisture cloud scheme.

We have installed Coupled Ocean-Atmosphere Modeling Prediction System (COAMPS) on our SGI Origin 2000 computer with 16 processors; the first testing is currently underway.

RESULTS

With the synthesis of observations and model results viewed in the Lagrangian framework, it appears that the cloud-top cooling and intense subsidence were paramount to fog formation. Radiative cooling at the stratus top along the air mass trajectory is the primary mechanism for the cooling and mixing of the marine layer. Subsidence acts to strengthen the inversion and forces lowering of stratus. It appears that there is an optimum inversion strength conducive to fog formation. The weak inversion induced stronger cloud-top cooling and production of more liquid water; however, fog formed at later time as compared to the baseline simulation. The strong inversion led to fog of limited duration and promoted fog dissipation. A positive heat flux at the sea surface tends to be of secondary importance as compared to cloud-top

cooling and subsidence. Moisture content of the air above the inversion alters cloud-top cooling and therefore influences the formation and evolution of fog. A detailed discussion of the study findings can be found in Koracin et al. (2000b).

Koracin and Dorman (2000) showed that the modification of the offshore flow in the near-coast zone (100 km) has a first order effect on the modification of coastal cloudiness. Their results have been obtained using simulated and evaluated dynamics and satellite-observed cloudiness for all of June 1996. The new set of MM5 simulations with a full explicit moisture scheme for all of June 1996 provides new insight into the prediction of coastal cloudiness and its diurnal variation. Currently we are testing various approaches in evaluating the modeled cloudiness using satellite data. In particular, we are comparing predicted and observed cloud top location, integrated liquid water content with satellite reflectance values, and pixel-type comparison of predicted and observed cloud and no-cloud occurrence within the model grid. Preliminary results indicate some success in predicting intense cloud development during the nighttime and early morning, as well as subsequent cloud clearing during the afternoon when the flow in the lees of major capes intensifies. Figure 1 shows early-morning cloudiness as predicted by MM5 and the corresponding GOES visible image for the western U.S. Figure 2 shows afternoon cloudiness as predicted by MM5 and the corresponding GOES visible image for the same area. These results support the findings by Koracin and Dorman (2000) that the intensification of dynamics along the coast during the daytime induces cloud clearing. The clearing starts from the north and propagates to the south due to a general increase of cloud mass associated with an increase of sea surface temperatures southward.

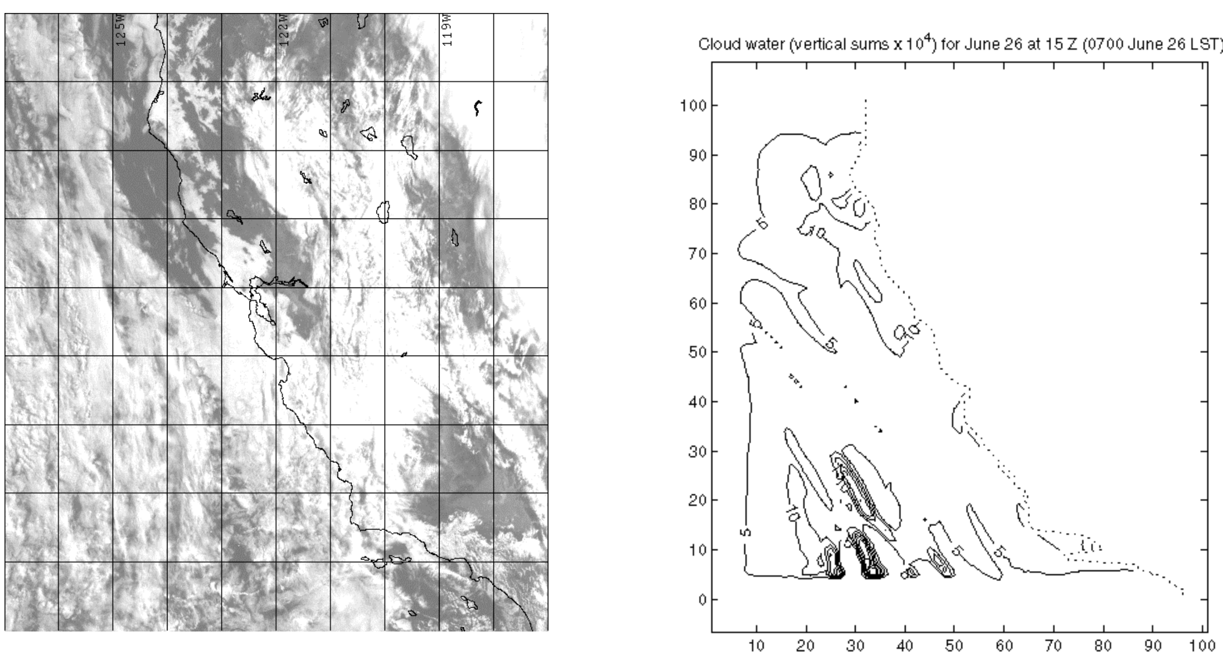

Figure 1. Early morning cloudiness on 26 June 1996 from GOES visible image at 0730 LST (left panel) and as predicted by MM5 at 0700 LST (right panel) for the western U.S.

We have just started to analyze the high-resolution simulation (horizontal resolution of 2 km) for the cases of gravity waves along the California coast. The main objective is to investigate the main reasons for the apparently infrequent occurrences of gravity waves along the California coast (C. Dorman, 2000,

personal communication). Preliminary results indicate that in some cases trapped waves could occur as a consequence of differences in atmospheric stability within and above the marine layer.

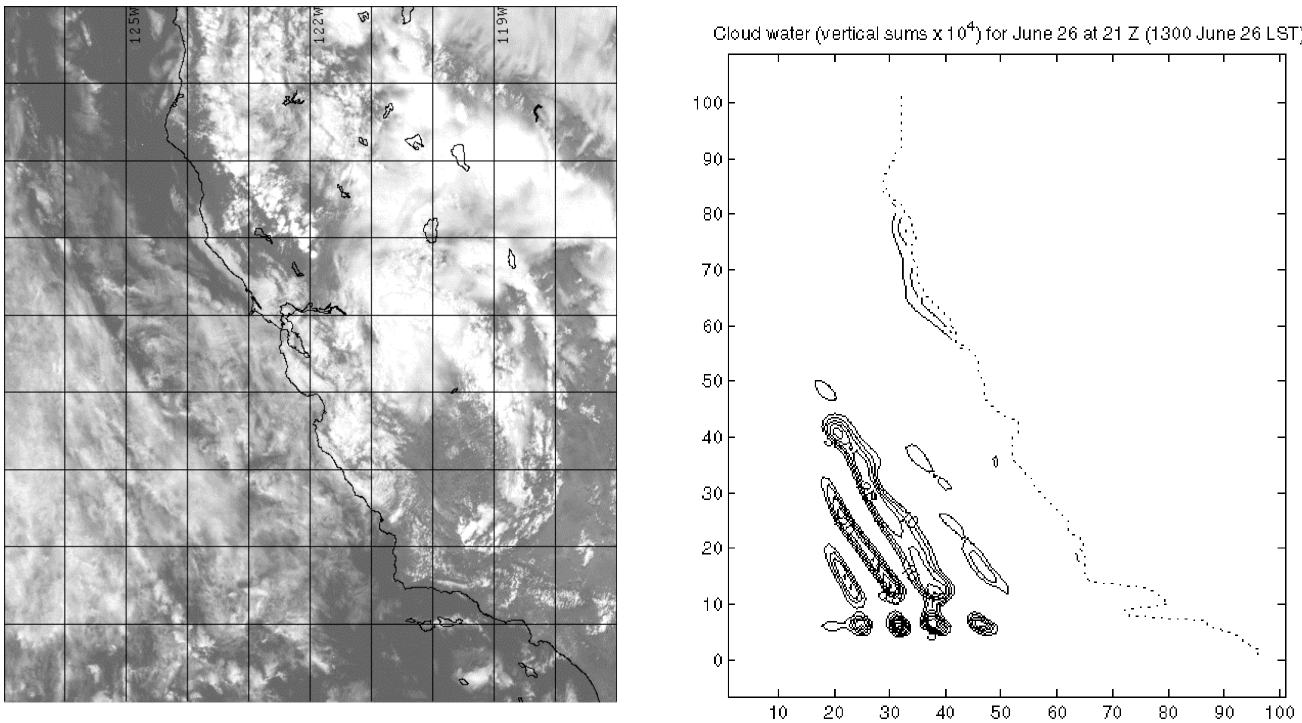

Figure 2. Afternoon cloudiness on 26 June 1996 from GOES visible image at 1330 LST (left panel) and as predicted by MM5 at 1300 LST (right panel) for the western U.S.

IMPACT/APPLICATIONS

The results of this study will improve the predictability of wind, turbulence, clouds, fog, and stable internal boundary layers in coastal areas. This will aid in decision making and in the performance of low-level airborne and sea-based naval operations. The results may be applied to other coastal areas worldwide.

TRANSITIONS

The experience and expertise in mesoscale modeling have led us to develop a novel approach of evaluating atmospheric models using tracer measurements (Koracin et al. 2000a). We simulated a strong wind (bora) case and its associated oceanic vortex in the Adriatic Sea observed in January 1987. The results have been used by our collaborators from Croatia (the Oceanographic Institute in Split) to drive an ocean model. They were able to reproduce a vortex observed in the northern Adriatic (Beg Paklar et al. 2000). We are further investigating the significance of gravity waves on the west coast with Dr. Clive Dorman of Scripps Institution of Oceanography, San Diego. Collaborators from the University of Uppsala (Mr. Ragoth Sundarajan) and the University of Stockholm (Dr. Michael Tjernström) are using our month-long simulation results (Koracin et al. 1997, 1998b; Koracin and Dorman 2000) and our Lagrangian random particle model (Koracin et al. 1998b) to study events of marine-layer intrusion over

the West Coast land. Mr. Sundarajan is preparing a joint article with Dr. Tjernstrom and the P.I. (D. Koracin) focusing on key results. We also collaborate with Dr. Gunilla Svensson of the University of Stockholm on simulations of the cloudiness transition observed in ASTEX (Svensson et al. 2000).

RELATED PROJECTS

1. The P.I. for this project was a P.I. on the DoD – DURIP – ONR awarded proposal entitled "Enhancement of high-resolution numerical simulations of atmospheric and dispersion processes using a multi-processor computer" (with co-P.I.s Drs. Steve Chai, Melanie Wetzel, and Mr. Jeff Tomer) to purchase a supercomputer SGI Origin 2000 with 16 processors. This award significantly enhances the mesoscale modeling capabilities of the P.I. and his collaborators at DRI.

2. Numerical simulations in complex terrain and a new method of evaluating atmospheric models using tracer measurements have been applied to another DOD-ONR project the P.I. conducted with Dr. S. Chai focusing on modeling the dispersion of vapor and aerosol particulates in complex terrain.

3. The P.I. for this project was awarded a contract by the Scripps Institution of Oceanography, San Diego, to perform high resolution numerical simulations using data assimilation focusing on the atmospheric and oceanic processes in Bodega Bay, to support their NSF-COOP project entitled "Wind Events and Shelf Transport".

4. The P.I. has received funding from the Washoe County Health Department, Reno, Nevada and developed an operational version of the MM5 model for Nevada and northern and central California. This real time forecasting tool with 6 km horizontal resolution on the nested grid currently provides a 48-hour forecast and has been applied to the prediction of weather phenomena and the atmospheric transport of atmospheric pollutants over the Sierras.

REFERENCES

Beg Paklar, G., V. Isakov, D. Koracin, V. Kourafalou, and M. Orlic, 2000: A case study of bora-driven flow and density changes on the Adriatic shelf (January 1987). Submitted for publication.

Koracin, D., 1989: Numerical Simulations of the Cloud-capped Marine Boundary Layer. Ph.D. dissertation, University of Nevada, Reno, 151 pp.

Koracin, D., and D. P. Rogers, 1990: Numerical simulations of the response of the marine atmosphere to ocean forcing. *J. Atmos. Sci.*, **47**, 592-611.

Koracin, D., and C. Dorman, 2000: Marine atmospheric boundary layer divergence and clouds along California in June 1996. Submitted for publication.

Koracin, D., V. Isakov, and J. Frye, 2000a: A method of evaluating atmospheric models using tracer measurements. *J. Appl. Meteor.,* **39**, 201-221.

Koracin, D., J. Frye, V. Isakov, D.F. Leipper and P. Saha, 1998a: Simulations of atmospheric dynamics during the Coastal Waves Program in June 1996. Second Conference on Coastal Atmospheric and Oceanic Prediction and Processes, Phoenix, AZ, 11-16 January 1998. Paper 4.7, 137-142.

Koracin, D., V. Isakov and J. Frye, 1998b: A Lagrangian particle dispersion model (LAP) applied to transport and dispersion of chemical tracers in complex terrain. Presented at the Tenth Joint Conference on the Applications of Air Pollution Meteorology, Phoenix, AZ, 11-16 January 1998. Paper 5B.5, 227-230.

Koracin, D., J. Lewis, W. T. Thompson, C. E. Dorman, and J. A. Businger, 2000b: Transition of a stratus into a fog along the California coast: Observations and modeling. *J. Atmos. Sci. (in press).*

Leipper, D.F., and D. Koracin, 1998: Hot spells and their role in forecasting weather events on the U.S. west coast. Second Conference on Coastal Atmospheric and Oceanic Prediction and Processes, Phoenix, AZ, 11-16 January 1998. Paper 4.5, 127-132.

Rogers, D. P., and D. Koracin, 1992: Radiative transfer and turbulence in the cloud-topped marine atmospheric boundary layer. *J. Atmos. Sci.*, **49**, 1473-1486.

Svensson, G., M. Tjernstrom, and D. Koracin, 2000: The sensitivity of a stratocumulus transition: Model simulations of the ASTEX First Lagrangian. *Bound.-Layer Meteorol.* **95**, 57-90.